DUNE Low Energy Reconstruction: Topics and Questions

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DUNE Reconstruction Summit @ LBNL

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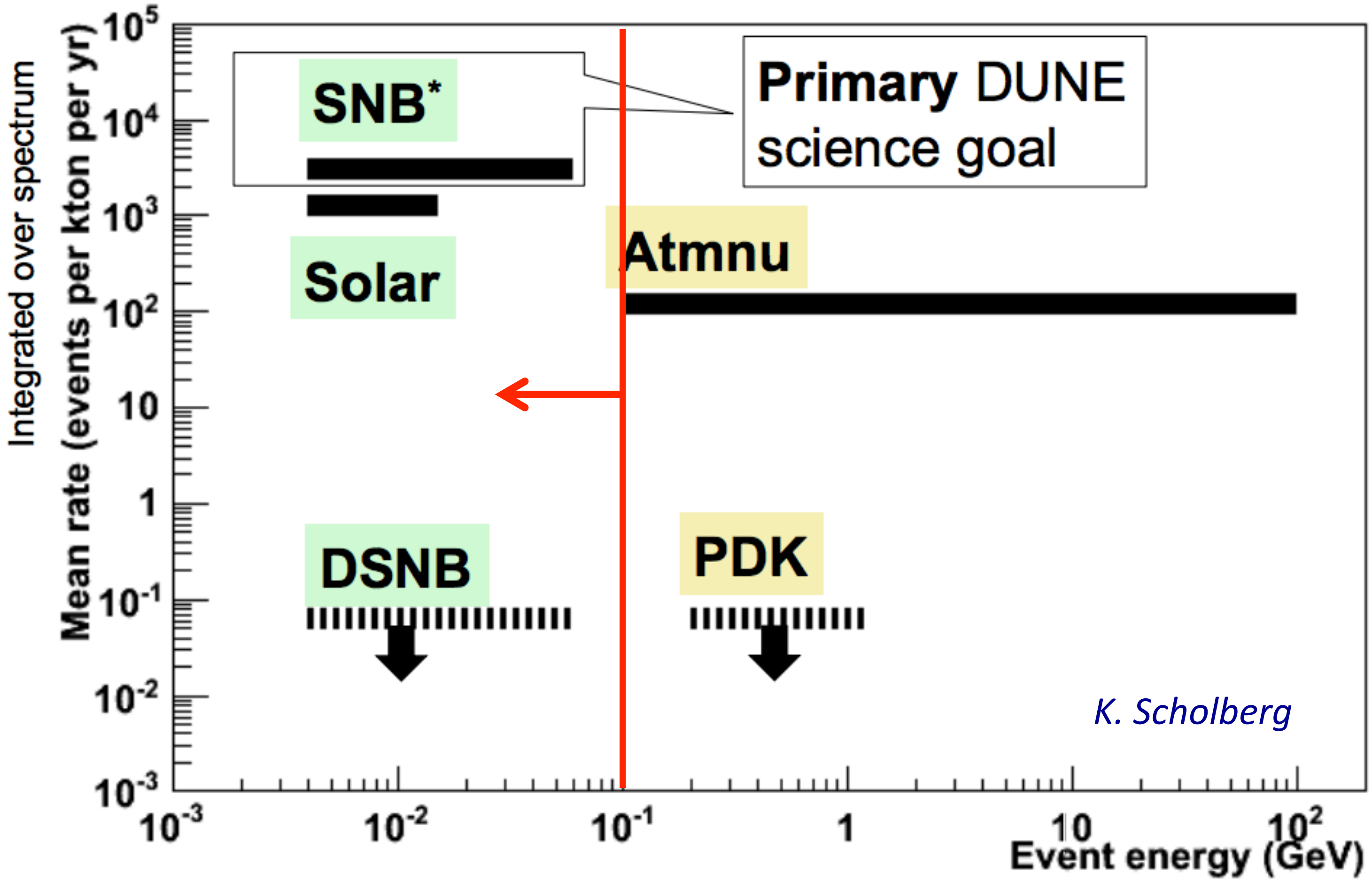
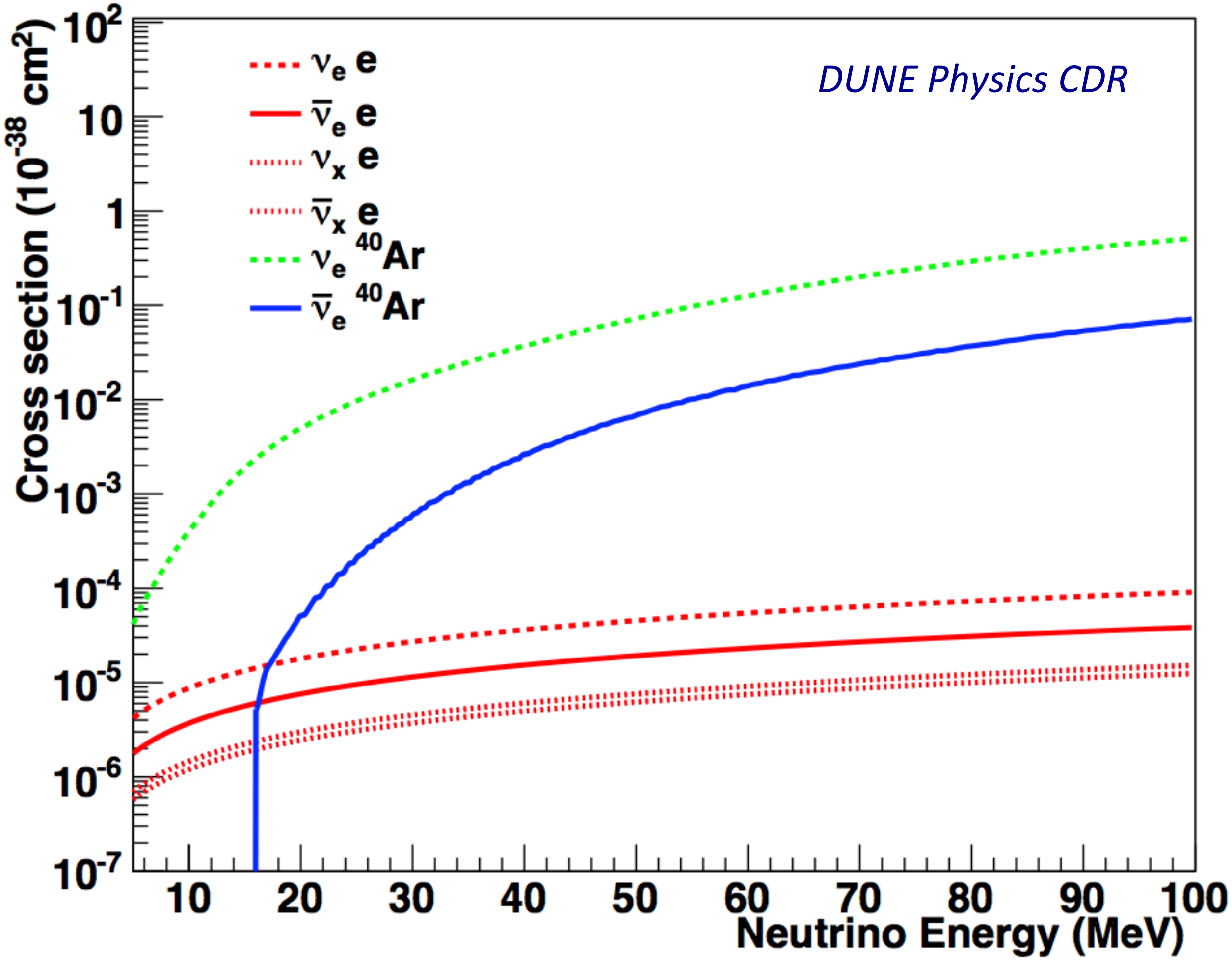
Low Energy Physics

Physics signals depositing < 100 MeV in TPC.



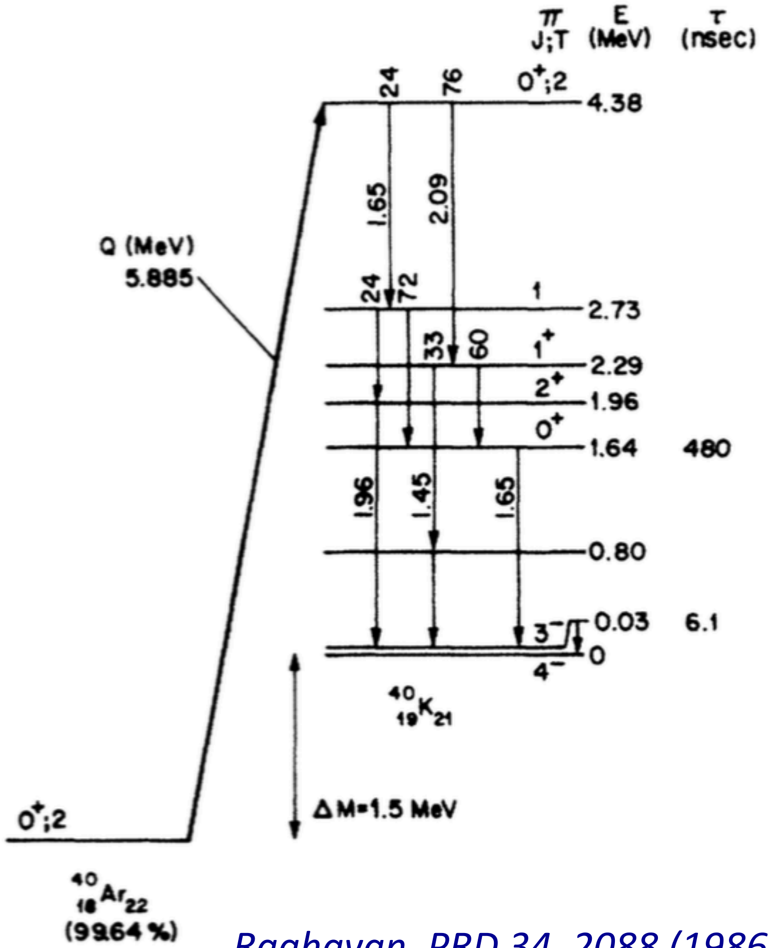
Low Energy Neutrino Interactions

Dominated by ν_e charged-current interactions on ^{40}Ar



Low Energy Neutrino Interactions

Nuclear state feeding versus neutrino energy is not known



Raghavan, PRD 34, 2088 (1986)

Inverse beta decay to ^{40}K GS unlikely
-> third-forbidden transition (0^+ to 4^-).

Transition to super-allowed 4.38 MeV state is most likely, estimated at ~30%.
-> $E_e = E_\nu - 5.885$ MeV

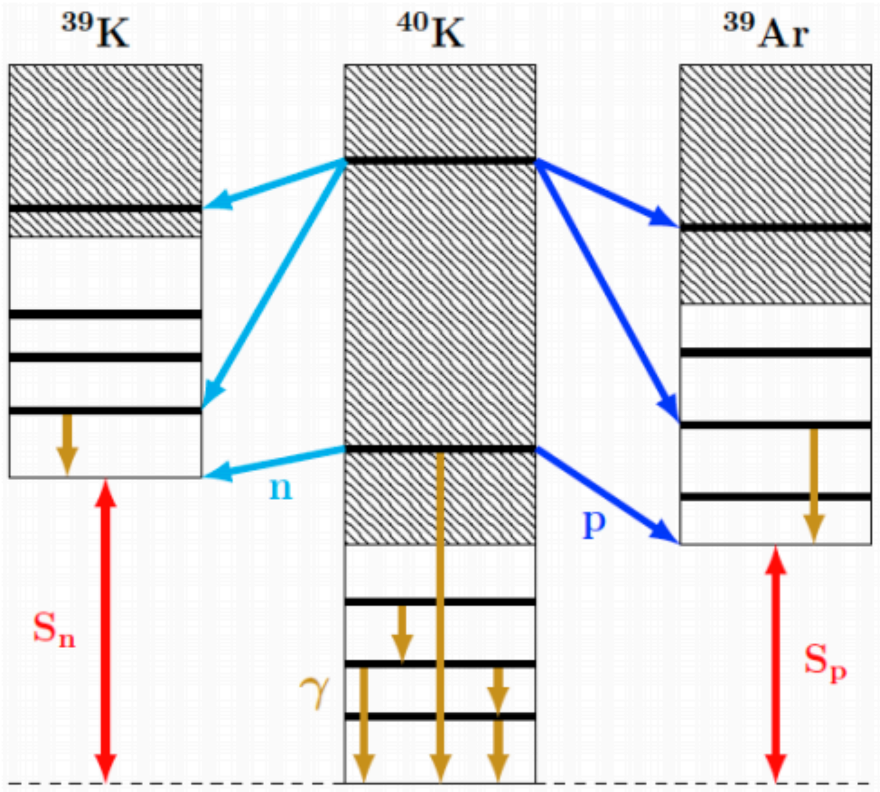
Relative feeding of excited states not precisely known.

Subsequent de-excitation γs are uncertain
-> Important for energy reconstruction

Metastable isomer (1.64 MeV, t = 480ns):
… another complication.

Low Energy Neutrino Interactions

Particle-unstable excitations are also a concern.



S. Gardiner (via B. Svoboda)

Highly-excited ^{40}K* can de-excite via n or p emission.
-> further complicates energy estimation.

Low Energy Neutrino Interactions

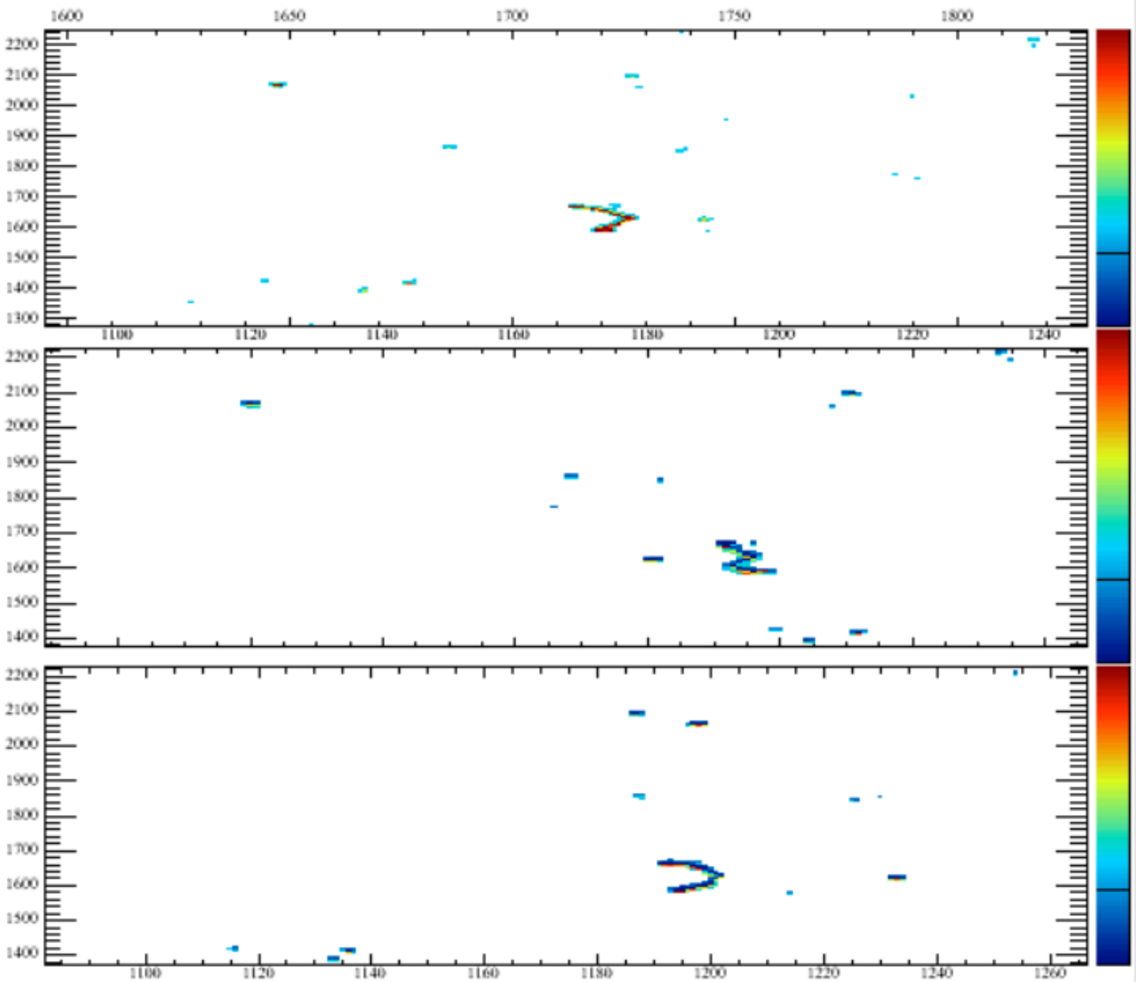
Simulated example: 20 MeV ν_e (14 MeV e-)

Deexcitation gammas produce diffuse compton-scatters.

Energetic e- also has significant probability of bremsstrahlung.

Question:
-> What is the expected energy resolution, given these nuclear effects?

K. Scholberg



Low Energy: T_0 Determination

Low energy sources are 'continuous'. How to determine time?

Current approach:
-> Use LAr scintillation photons

Problems:
-> Current DUNE design predicts ~1 detected photon per 10 MeV.

Scintillation Background:
-> ^{39}Ar: ~1 Bq/kg.

Improve photocoverage?
-> Increases sensitivity to background.

^{39}Ar photon background (in 2.7% of far detector)

Thresh.	SN ε	Bkgd
2 PE	98%	81 kHz
5 PE	76%	1.3 kHz
10 PE	50%	20 Hz

A. Himmel

Low Energy: T_0 Determination

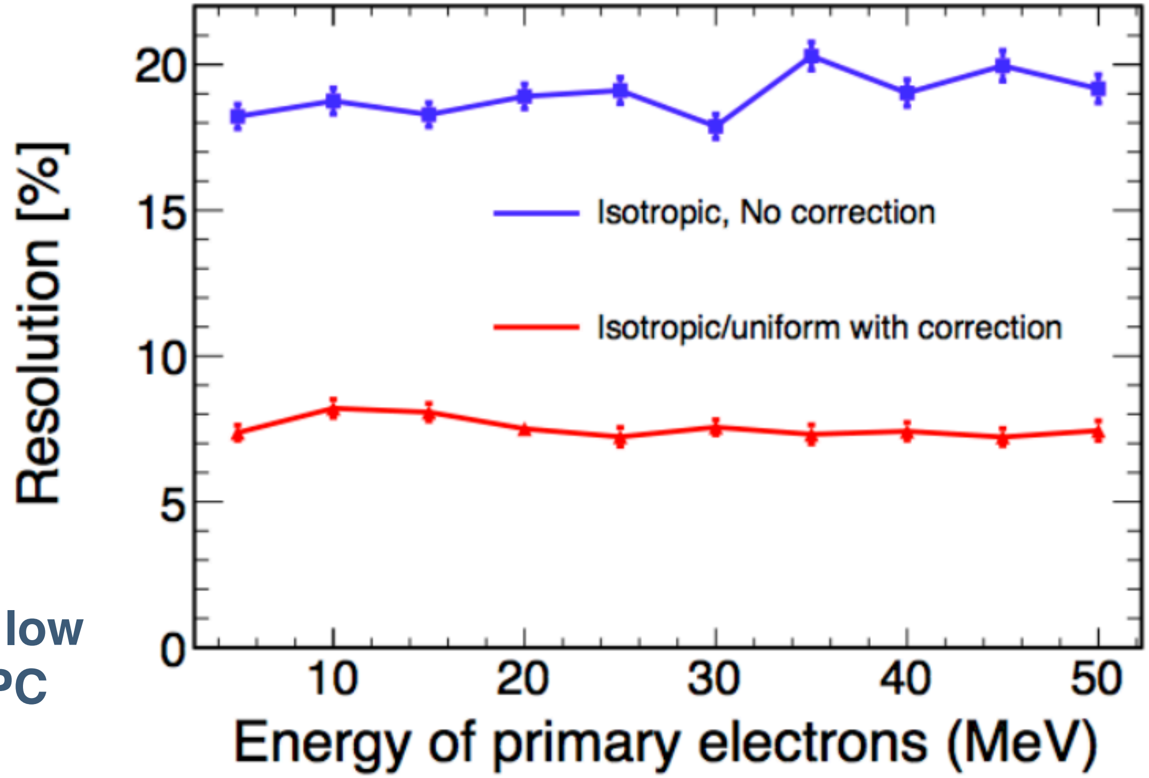
Without T_0, detector energy resolution significantly poorer.

Unable to correct for e- loss versus drift distance.

Resolution depends on drift distance and e- lifetime.
-> Could be worse for DUNE

Also lose fiducialization.
-> Introduces risk of increased low energy backgrounds from TPC boundaries.

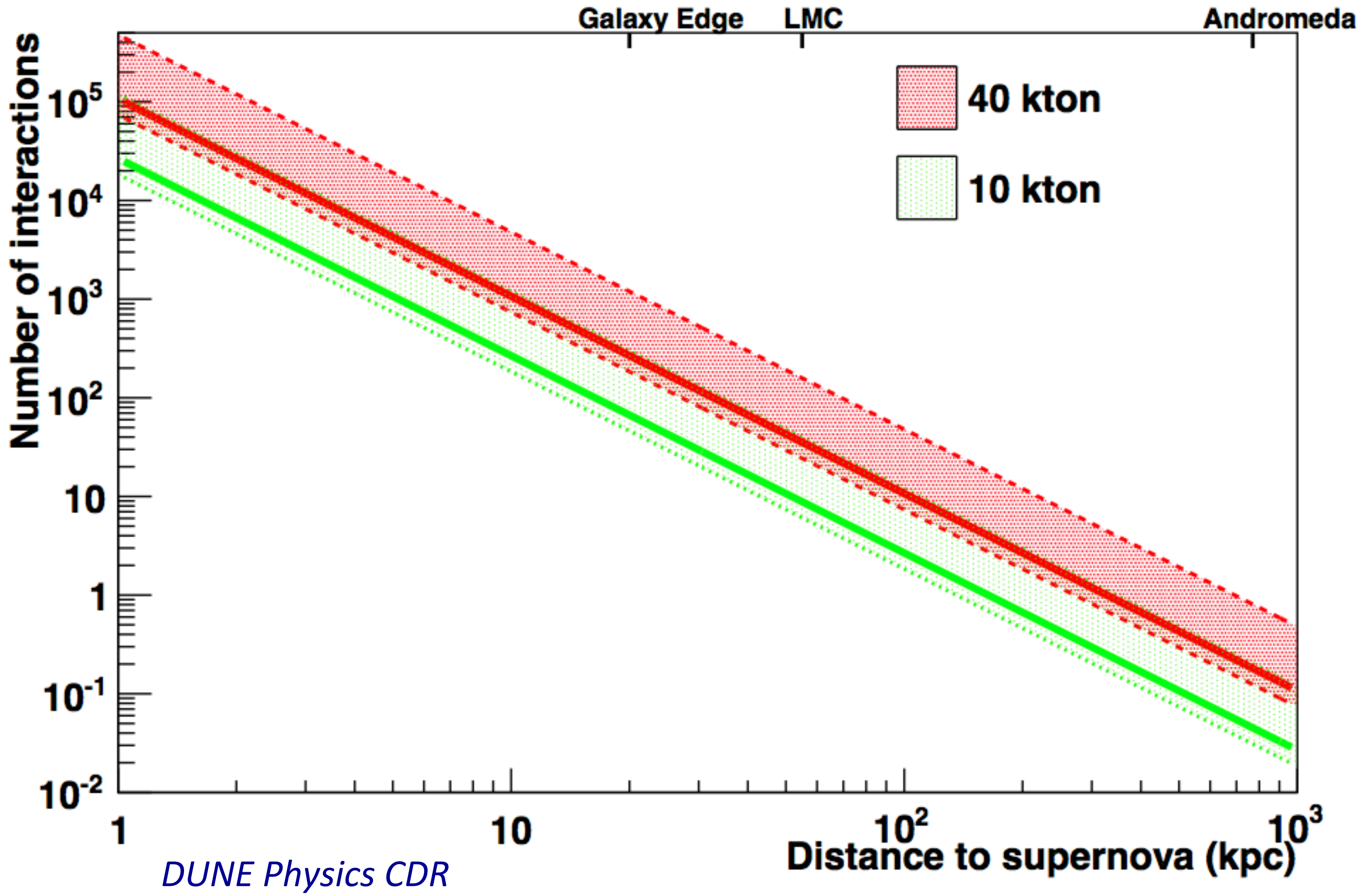
MicroBOONE simulation (2.5m drift, 3ms e- lifetime)



Z. Li (via K. Scholberg)

Supernova Neutrinos

Interactions per SN burst depends on distance (~3000 @ 10 kpc)



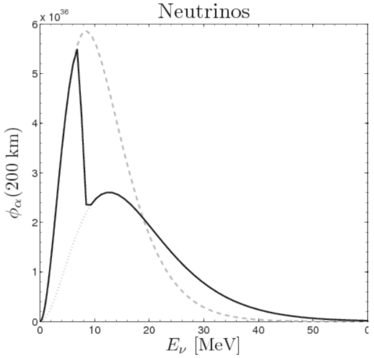
DUNE Physics CDR

Supernova Neutrinos

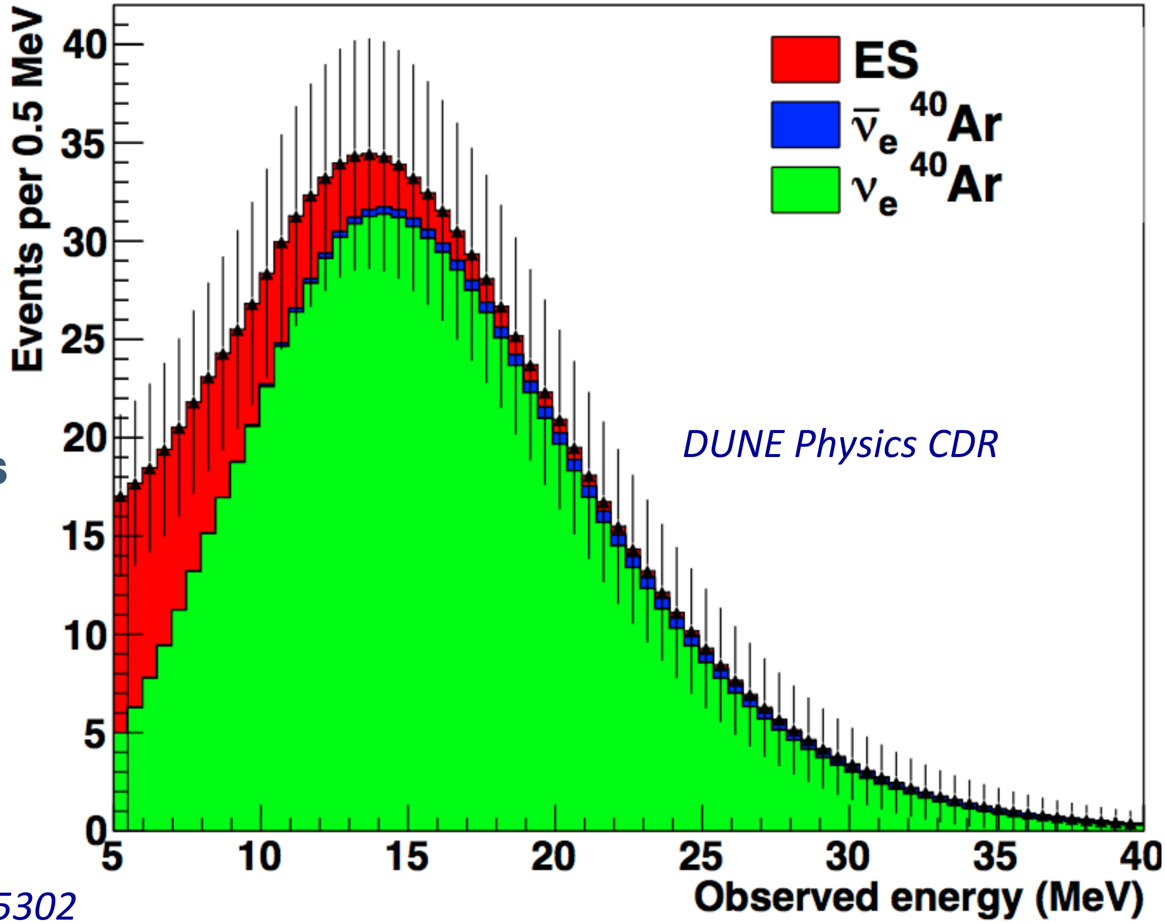
Nominal interaction energy spectrum at 10 kpc.

Significant model uncertainties in spectral shape:
-> supernova dynamics
-> neutrino properties

Energy resolution requirements difficult to define.
-> Closer the SN, more demands on detector resolution.



e.g. arXiv:1103.5302



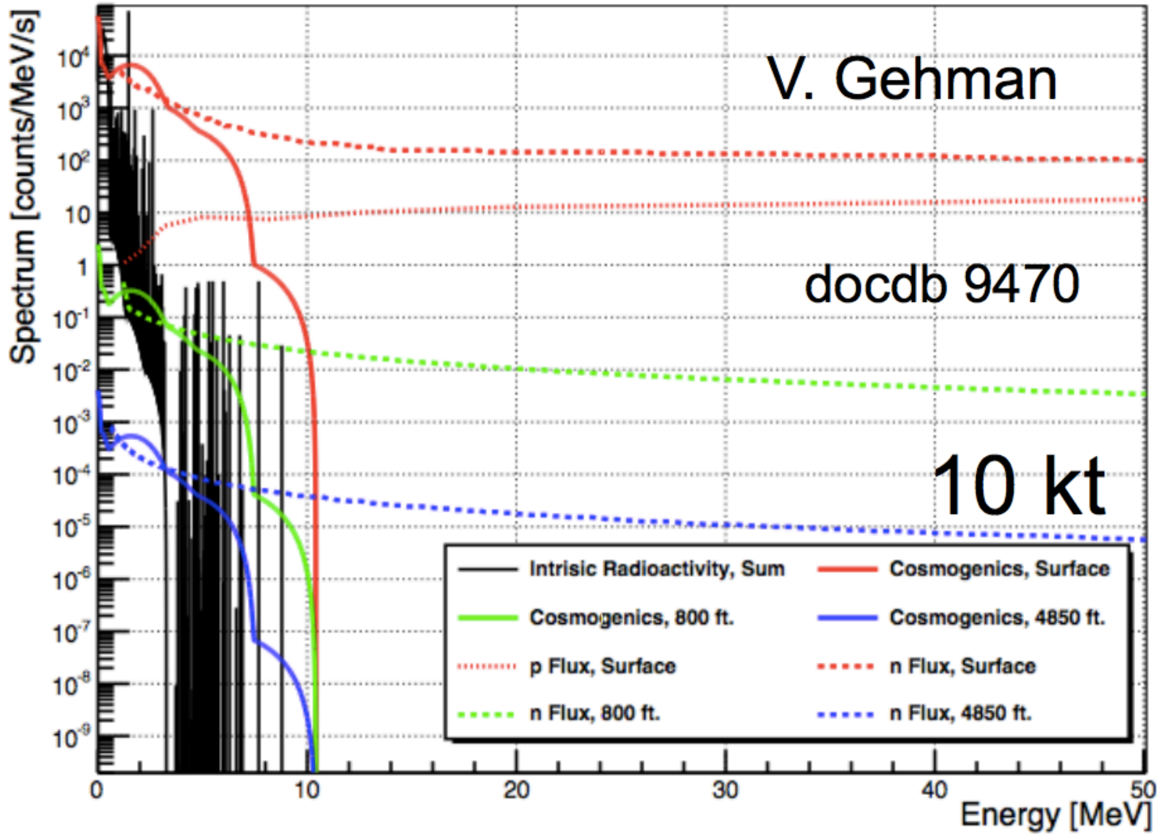
Solar Neutrinos

Expect ~100 solar neutrino interactions per day (40 kton).

Issues:

Interaction threshold (5.9 MeV):
-> Limited to ^{8}B physics.

Negligible photon detection:
-> Poor energy resolution
-> No fiducialization, likely overwhelming BG



V. Gehman (via K. Scholberg)

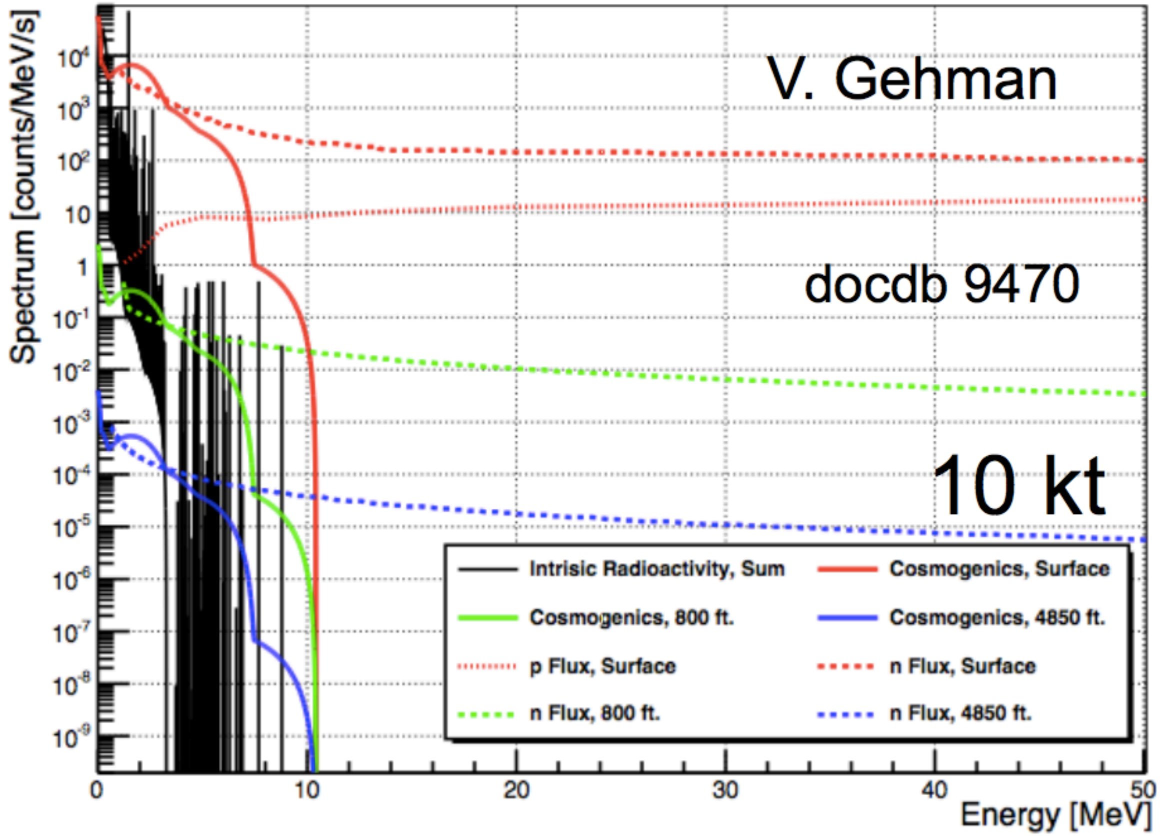
Diffuse Supernova Background

Expect up to 4 DSNB neutrino interactions per year (40 kton).

Issues:

Very low expected rate:
-> Backgrounds overwhelming

Limited photon detection:
-> Poor energy resolution
-> No fiducialization



V. Gehman (via K. Scholberg)

Summary

Low Energy Reconstruction:

Complicated by:

-> Nuclear uncertainties in $^{40}K^*$ excitation and decay

-> Likely lack of T_0, resulting in poor energy resolution and loss of fiducialization.

Supernova Neutrinos:

Spectrum uncertain, rate strongly dependent on SN distance.

Is 20% energy resolution sufficient for SN at 10 kpc?

Solar Neutrinos:

Difficult to measure signal, and has limited new physics potential.

Diffuse Supernova Neutrino Background:

Very difficult (impossible?) to measure in DUNE.